Sea Truth validation of bio-optical models for 'a' and 'b_b'; application to heat budget models and the effects of biology on ocean thermal structure.

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LONG-TERM GOALS

The long-term goal is to obtain better measurements of the inherent optical properties of seawater (IOPs, absorption 'a' and back-scattering 'b_b') to provide better parameterisations of the absorption of light by seawater, to improve heat budget models of surface ocean stratification. The proposed work will extend on-going research at PML on furthering the understanding, accurate interpretation and exploitation of remotely sensed data of ocean colour, from sensors: SeaWiFS, MODIS (NASA), MERIS (ESA). Assimilation of data from these sensors into 1-D and 3-D ocean circulation models is a long-term goal.

OBJECTIVES

The primary objective is to develop bio-optical models, that will have the inherent optical properties (IOPs, absorption 'a' and back-scattering 'b_b') as the main variables, so that remotely sensed data of ocean colour can be interpreted and exploited by including the effects of absorption and scattering of solar radiation in heat-budget models of upper-ocean physical structure to improve accuracy. The work with ONR will focus on model validation, acquiring ground-truth data and in situ measurements of the IOPs and AOPs (inter-relationships). The effects of biology (phytoplankton) on vertical thermal structure will be studied.

The development of bio-optical models, with IOPs as the main variables, is on going and part of the core strategic projects of PML, part funded by NERC. The acquisition of ground truth data of IOPs is new, which ONR/NICOP are requested to provide part funding.

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14. ABSTRACT
The long-term goal is to obtain better measurements of the inherent optical properties of seawater (IOPs, absorption ???a??? and back-scattering ???bb???) to provide better parameterisations of the absorption of light by seawater, to improve heat budget models of surface ocean stratification. The proposed work will extend on-going research at PML on furthering the understanding, accurate interpretation and exploitation of remotely sensed data of ocean colour, from sensors: SeaWiFS, MODIS (NASA), MERIS (ESA). Assimilation of data from these sensors into 1-D and 3-D ocean circulation models is a long-term goal.

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APPROACH

Year 1 was focused on the acquisition of new IOP data, which necessitated the commissioning of new equipment and the development of new optical profiling apparatus, combining existing AOP and new IOP sensors. These developments were implemented sequentially as new sensors were delivered, so that the on-going time series of data acquisition at station L4 in the western English Channel was uninterrupted. New data from new sensors has been patched on to the n-year series of bio-optical data so that common seasonal features could be identified. Existing data sets (of varying length 3-5 year for different variables) exist for: diffuse attenuation coefficients k(λ), beam-c, remote sensing reflectance R(λ), chlorophyll-a, pigments, SPM, coloured dissolved organic matter (CDOM, or a_{CDOM}). New data on IOPs (absorption, scattering and back-scattering) can be added on as acquired. Throughout 2002 and 2003, the time series of Optical measurements and bio-optical variables at L4 have continued, supplemented since April 02 by new IOP measurements, ac-9 and VSF and later the bb-6. Continued difficulties have arisen on data analysis, due to incompatibility of manufacturers software in the combinations employed. Supplementary measurements were taken for pigments, particle absorption, TSM and CDOM. In addition data from all sensors (ac-9, VSF, miniTraka, Ed, Lu, CTD) have been acquired on several research cruises, notably the BENCAL cruise on FRS Africana in the Benguela Ecosystem, offshore from the Republic of South Africa, October 1-14, 2002. The cruise sampled bio-optical conditions ranging from 0.25 to > 30 mg.m-3 chlorophyll concentrations.
We have also found that the manufacturer's analysis software supplied only work under best conditions, this applies to both the IOP and AOP instruments. Extensive analysis software has been developed that allows interactive editing of profiles and better data screening of data. In addition to this we have performed controlled validation experiments for the IOP instruments using suspended particles in tanks that allows us to calibrate the instruments and achieve optical closure with AOP observations.

WORK COMPLETED

During the year under review (Oct 2002 to Sept 2003) the following accomplishments were achieved (Data lists are in appendices 1 to 6):

1. Data acquisition in the western English Channel at station L4 (approximately weekly, Appendix 1) and at station E1 (monthly, Appendix 2) for the year 2002 was completed.
2. Data were acquired in the Benguela Ecosystem, offshore from the Republic of South Africa, October 1-14, 2002, on FRS Africana (Appendix 3).
3. Data were acquired in the western English Channel at station L4 (approximately weekly A4) and at station E1 (monthly, A2) from Jan to September 2003.
4. Data were acquired on the Atlantic Meridional Transect cruise (AMT-12), from Falkland Islands to the UK, May-June, 2003, on RRS James Clark Ross (A5).
5. Analysis of L4 and E1 station data for the period 2001 to Sept 2003 was continued.
6. Analysis of data acquired on the PML spring bloom cruise on the Celtic Shelf, 1-14. April 2002 (D261, MDB402) continued (see station list A6).
7. Analysis of data for Benguela cruise October 2002 continued.
8. Analysis of data for AMT-12 cruise May-June 2003 continued.
9 Full inter-calibration of all the instruments used in the cruises.

The data is being post processed and banked in a local database that can provide output compatible with the WOOD database. We would hope to stat providing the data to this database in early 2004.

Due to the intensity of effort in data acquisition in field campaigns over the past 18 months, data processing and analyses has been restricted. Currently as the 2003 season (annual cycle at L4) draws to a close, effort is being re-directed to the analysis of the data backlog.

RESULTS

As an example of the data acquired and now being processed, we present results from the recent AMT-12 cruise from Falkland Islands (50 S) to the UK (50 N), May-June, 2003, on RRS James Clark Ross. As a example of the spatial extent of the AMT data Figures 1 and 2 show the along track data of absorption a and back scattering to scattering ratio $\tilde{b}$ optical properties derived from the casts of the ac-9 and the VSF-3 (30 stations).

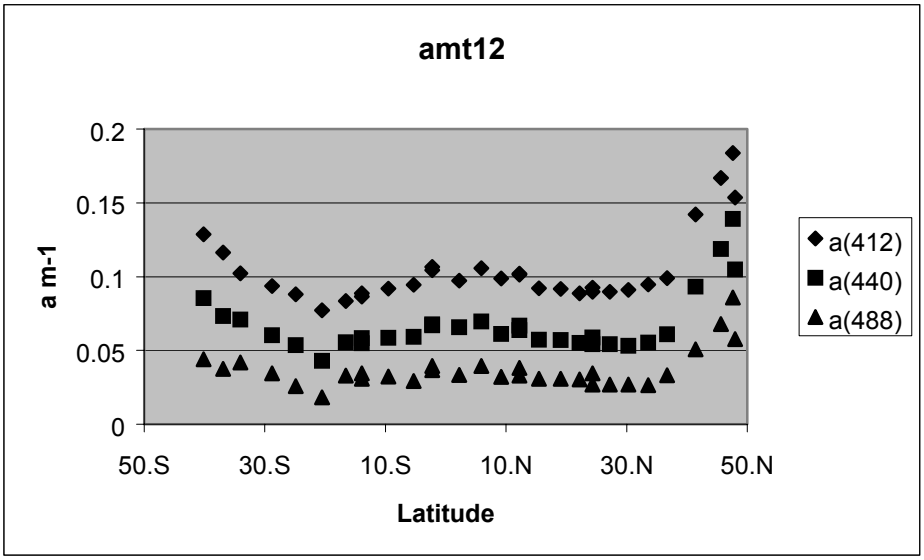


Figure 1Along track profiles of absorption at 412, 440 and 488 nm. The data extends from 40 S to 50 N. At the tropics (26 south / north) the absorption is at a minimum, approaching that of pure water. There is a peak of absorption of 0.2 m-2 at 47N due the North Atlantic spring bloom. Some points (e.g.) at 12S at near the same locations practically overlap, giving some measure of the reproducibility of the data.

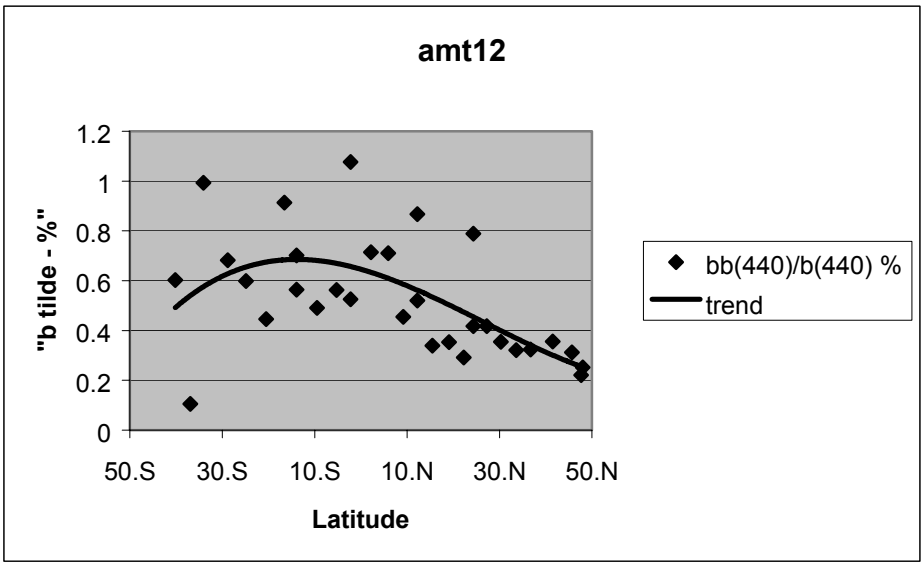
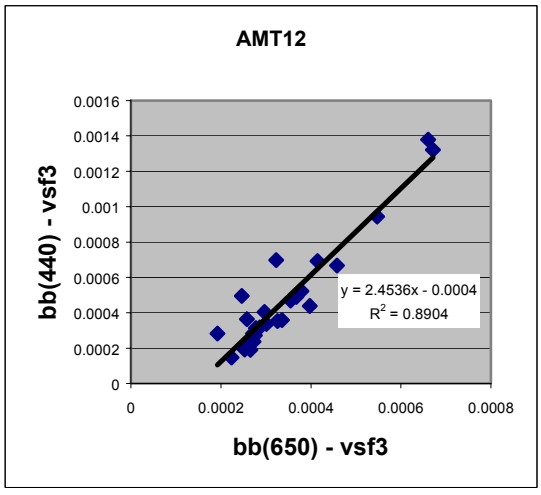


Figure 2:This shows the same spatial extent as figure 1 above. The backscatter ratio $\tilde{b}$ changes from around 1 % in tropical latitudes to 0.4 % in temperate latitudes.

The value of $\tilde{b}$ is rather low that that cited in the literature for temperate regions and at present we are fully validating the calibration of the VSF instrument. If the low figures are correct then there an implication for the retrievals IOPs from reflectance either from *in-situ* or remotely sensed measurements. Figure 3 below shows the spectral variation of scattering and backscatter for the transect shown in figures 1 and 2.

A



B

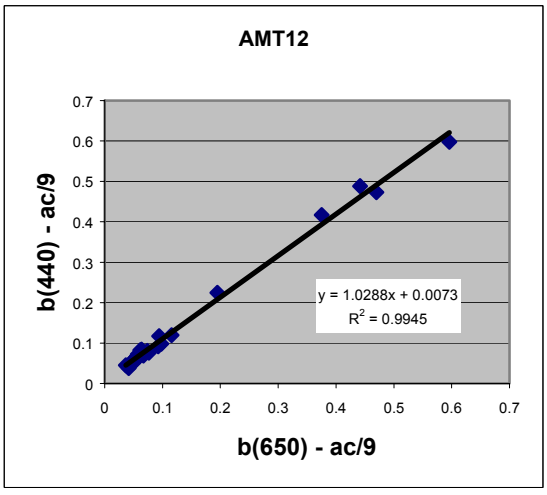


Figure 3.:Panel A (left) shows the relationship between backscatter at 440 and 650nm and panel B (right) shows the corresponding data for scattering. Although both are correlated the slope is significantly different.

The results above show that there may be a substantial difference in the spectral slopes of the scattering and backscattering values. These observations have been incorporated into models that can retrieve IOPs from remotely sensed data. An example is shown below

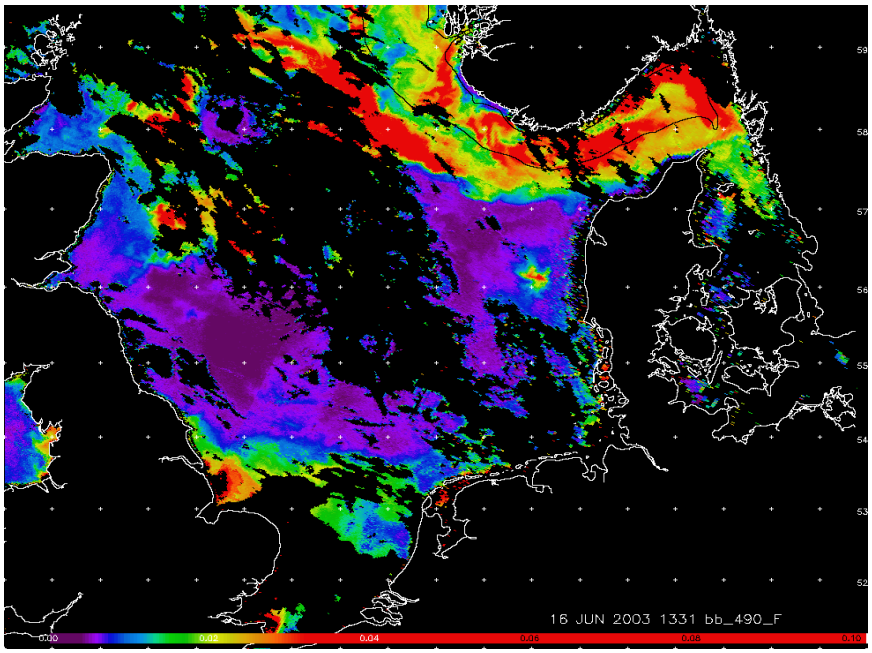


Figure 4: Backscatter retrieved from the SeaWiFS over the North Sea in June 2003. The figure shows sediment plumes from the Wash and the Thames Estuary (bottom left). Re-suspension

With the momentum on data processing now gaining pace, we intend to submit data reports on all the activities listed above at bi-monthly intervals, over the next few months. We are also now incorporating preliminary data into bio-optical models and trying to establish closure with IOPs.

IMPACT

These are truly novel measurements over widespread geographical distributions that combined with the local measurements at L4 south of Plymouth in the western English Channel, will allow us to assess the global variability of these variables.

TRANSITIONS

We expect the data to be available on the WOOD database in early 2004.

RELATED PROJECTS

Work with space agencies NASA and ESA on sensor validation as preparatory to exploitation of ocean colour data for IOP measurements (a, bb).

PUBLICATIONS

A bio-optical model for the determination of inherent optical properties from reflectance data: applications to remotely sensed data from case I and case II
waters. G. F. Moore and J. Aiken. Submitted applied optics, accepted subject to modifications.